BCI Applications :-

- → Device control
- → User state monitoring.
- → Training & Education
- → Games & Entertainment.
- → Cognitive Improvement
- → Safety & security.

Brain Activity :- (EEG, FNIRS, MEG)

Challenges :-

- → Usability
- → Hardware
- → Signal processing
- → System Integration
- → Cost :-

{ Central nervous System (CNS)
Peripheral nervous System (PNS) — Somatic NS, Autonomic NS

Sensory neurons → Interneurons → Motor neurons

$[Na^+]$, $[Cl^-]$, $[Ca^{+2}]$ → higher outside

$[K^+]$, $[A^-]$ Anions → higher inside.

Axons contains myelin — Synapses [chemically gated]

Excitatory synapses — Increase — Depolar

Inhibitory synapses — Decrease — Hyperpol

IONIC CHANNELS

- Voltage gated
- chemically gated
- Mechanically gated

LTP (Long Term Potentiation) *

→ Increase in the synaptic strength of a synaptic connection between two neurons caused by correlated firing of 2 neurons

→ Measured as increase in EPSP.

LTD (Long Term - Depression) ↗ reverse

STDP (Spike Timing Dependent plasticity)

→ Timing between presynaptic & postsynaptic spikes.

PNS :-

→ Somatic / Skeletal Nervous System
  → Nerves that are connected to Skeletal muscles & sensory receptors.

→ Autonomic NS :-
  → Connected to heart, blood vessels, smooth vessels, glands

22/3/22

→ Invasive approaches :-
  Techniques that involve recording of ~~signal~~ individual neurons.

1) Microelectrodes - Simply thin wire
2) Intracellular Recording - Measures voltage across membrane of brain tissue
3) Extracellular Recording.
  - Recording of a single neuron at brain target area.
4) Tetrodes & Multi-unit Recording
  Four wires, multiple neurons.
5) Multi-electrode arrays
  Larger number of neurons

Synaptic plasticity :-

→ short term facilitation :-

Effects of successive spike is greater than predecessor

→ Short term Depression

Hebbian STDP :-

Presynaptic spike occurs before postsynaptic spike → Synapse strength ↑

Presynaptic spike occurs after postsynaptic spike → synapse strength ↓

Partially Invasive Approaches :-

1) Electrocorticography (ECOG) :-

→ Placing electrodes on surface of the brain

2) Micro ECOG :-

micro electrodes [fraction of mm in diameter]

placed 2-3 mm apart in a grid

3) Optical Recording : [Voltage sensitive-dyes & Two photon calcium imaging]

→ neurons are stained with voltage-dye

→ change in membrane potential is responded by flouroscence

Non-invasive approaches :

1) Electroencephalography (EEG)

Summation of post synaptic potentials of thousands of neurons

→ Measured at cerebal cortex.

→ 10-20 system specify standardized electrode locations on scalp.

→ EEG Electrode one input → differential amplifier
other input — reference electrode

Amplified → Filter → A/D → Bandpass filter [1-50 Hz]

Am decreases ← Gain → freq dec

EEG measures
→ Brain waves (BATD).

2) Magneto encephalography (MEG):-

Measures the magnetic activity of thousands of cortical neurons

3) fMRI (functional Magnetic Resonance Imaging)

4) FNIRS

→ Neurotransmitters to ligand-gated ion channels

EEG measures
- volume conduction
- Neural activity
  ↓
  [Action potentials, Postsynaptic pot]
- Differences in electric potential at scalp.

EEG is non-invasive, covers whole head, very high temporal resolution

→ Neurons must give rise to a net dipole current

Hans Berger (1929) - EEG

Nasion | Frontal | Central | ~~Parietal~~ Parietal | occipital | Inion

Frontal

Auricular Tem. Central Tem Auricular

Parietal

Occipital.

A-G, R-G

Ground → voltages are measured
↓
Diff between participating amplifier.

Active
Ground
Reference.

→ Measuring EEG :-

EEG records potential diff at scalp by using a set of electrodes.

Bipolar: [Between adjacent electrodes]
Unipolar [Between electrode & designated reference]

10-20

EEG Paradigms :-

ERP (Event Related Potential)

→ Measured brain response that is result of thought or perception.

Categorization of EEG Based BCI paradigms :-

→ Evoked (Subject attention is req)
→ Spontaneous (No continuous attention is req.

ERD / ERS — Spont

P300 — Evoked

SSEP / AEP / VEP — Evoked

SCP — Spont

ERP → Averaging of trials following a stimulus

- VEP (Visual Evoked potential)
- SSVEP (Steady-state - - -)

P300 → 95% accuracy at 1 char per 26 sec

ERS / ERD > P300 > SSVEP

Time Taken to train

EEG waveform representation [Montage]

→ Sequential montage

→ Referential montage

EEG variables →

Frequency — Rhythmic repitative activity (Rhythm, Arrhythmia, Dysrhythmia)

Voltage — Avg voltage or peak

Morphology — Shape of waveform

EEG Rhythms

Cam BAT

730 | 16-30 | 8-15 | 4-7 | 1-4

Fourier introduced the concept that sine & cosine fns forms the basis orthogonal basis of soln fns.

Arbitrary fn $= \frac{A_0}{2} + \sum_{k=0}^{\infty} [A_k \cos(kx) + B_k \sin(kx)]$

FFT? FIFT?

Wavelet

$$A_k = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \cos(kx)\, dx$$

$$B_k = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin(kx)\, dx$$

Fourier series for complex fn

$$f(x) = \sum_{k=-\infty}^{\infty} C_k e^{ikx}$$

Spatial Filtering

Laplacian

Filtering :

- Spatial Filtering.
- Bipolar.
- Laplacian
- Common average reference

Discovers

PCA :- Underlying statistical variability in data.

→ Reduce the data dimensionality. [max variance]

PCA Steps :-

1) Compute sample mean
2) Subtract sample mean [Center data at 0]
3) Compute sample covariance matrix
4) Compute eigenvalues (eigenvectors of Σ)
5) Dimensionality Reduction step [approximate x using first K eigen vectors.]

[finding directions of max variance in D-dim data]

Normalization
- zero mean
- Unit standard deviation.

Decorrelation

Correlated multivariate distribution

↓

orthogonal linear combinations of original variables

PCA Reconstruction :-

PCA Re-- = PC Scores · Eigenvectors^T + mean